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AMS_02

BAFFLE Support Design

April 2005

Rev.1 (27/ 06/ 2005)

The object of this report is the design of the mechanical support of the Baffle that protects the lens of the Star Tracker.
The Amica (Astro Mapper for Instrument Check of Attitude) Star Tracker Camera (ASTC) is an optical system able to autonomously determine, in real time, the instantaneous AMS-02 pointing direction. Two identical ASTC will be mounted on AMS_02 at opposite locations (fig.1).
The Baffle design is responsibility of the Center for Advanced Research in Space Optics (CARSO) in Trieste Italy. The design of the mechanical support is developed by INFN of Rome Sez.1 and is described in the following paragraphs.

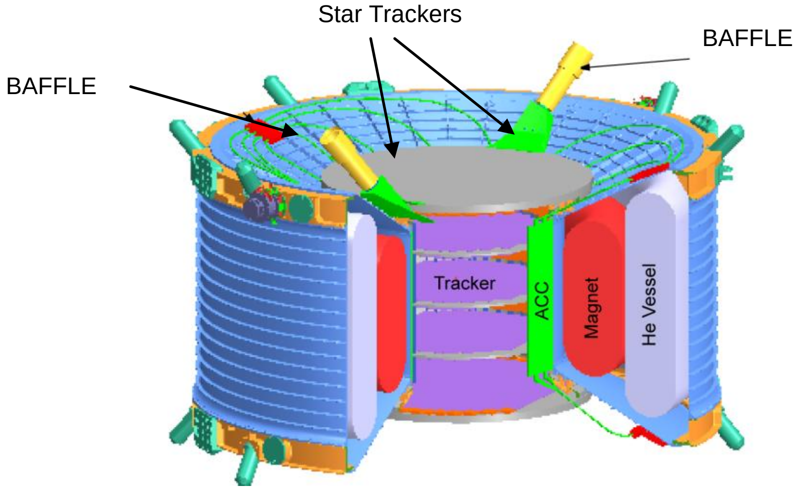

Fig. 1 Baffle locations in AMS_02

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1. Introduction

The baffle avoids that direct light or light reflected from AMS_02 or from the International Space Station enters the lens system compromising its functionality.
The baffle is a cylindrical metallic pipe 369mm long, 1mm thick with a circumferential cross section 104mm in diameter in the first portion and 130 mm in the last. The trap for the light is achieved by a series of internal sets (fig.2).
The baffle is made of aluminum alloy Al 6061 T6 and is internally black anodized and externally covered by silver Teflon.

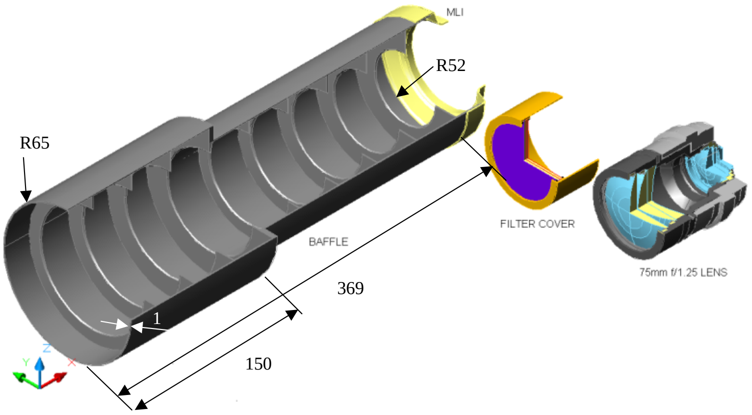


Fig. 2 Baffle geometries

Baffle is not mechanically connected to the lens, and then it is not supported by the Star Tracker support but is attached to the TRD M-structure by a devoted bracket.

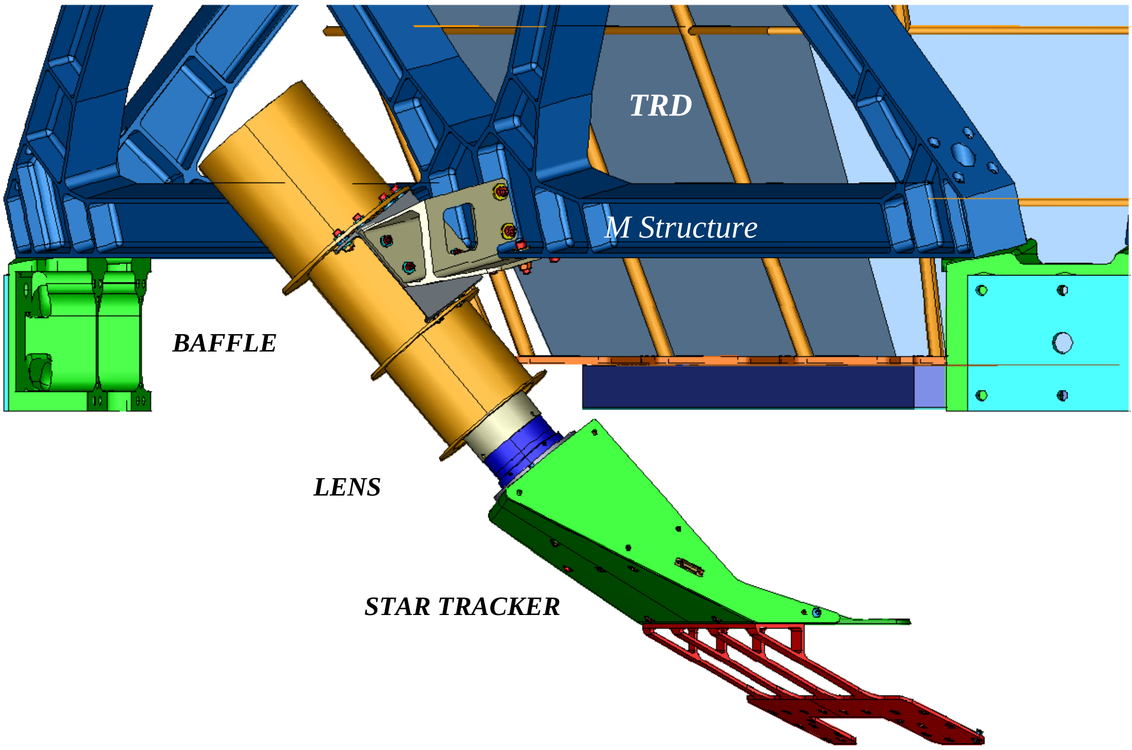


Fig. 3 Baffle Vs M-structure

2. Design

2.1 Design purposes

The baffle bracket absolves the following functions:

takes baffle in position
supports the baffle weight
minimizes the baffle thermal coupling with the M-structure

Bracket supported masses are:

baffle=0,850 kg

Bracket dimensional constrains are defined by:

integration with nearby AMS_02 hardware
integration with MLI
attachment to the M-structure.

Baffle bracket Structural requirements follow:

Launch:
-Structure must survive a static acceleration vector of (40,10, 10)g,
-Structure design has to guarantee a first frequency > 50 Hz.
according to Document JSC 28792

Space environment:
-Structure has to avoid or at least minimize the conductive link between Baffle and M-structure

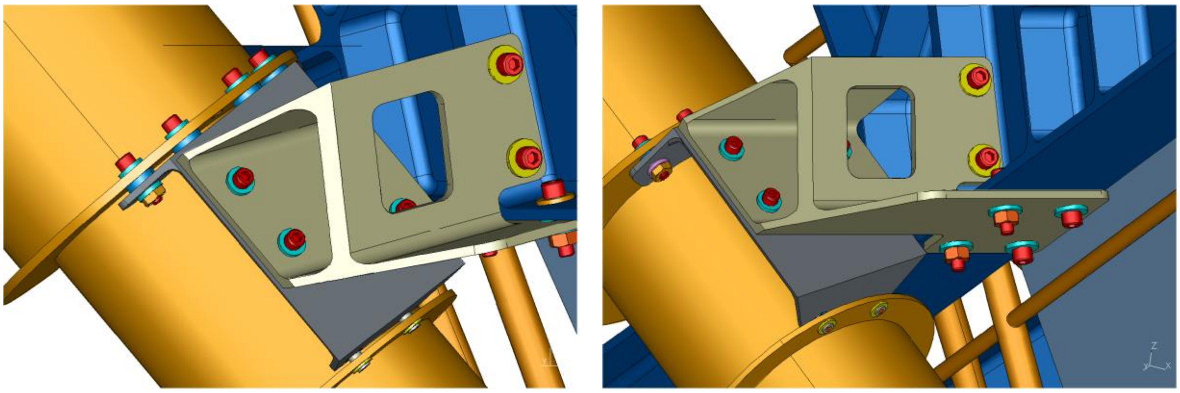


Fig. 4 Baffle bracket

2.2 Geometries

The bracket consists in two parts for easy of assembly (fig.4):

1) **B**affle **B**racket **M**-structure side (**BBM**) is an aluminum alloy light part bolted to the M structure.
2) **B**affle **B**racket **B**affle side (**BBB**) is the bracket attached to the baffle at two external rings.

Four 0.19x32 bolts connect the two brackets.

2.2.1 *BBM bracket*

BBM bracket is an A7075 T7351 milling machined part bolted to the M_structure lower beam by six 0.25-28 bolts, and connected to the BBB bracket by four 0.19-32 bolts.
The bracket is pre-assembled to the M-structure (fig.5).

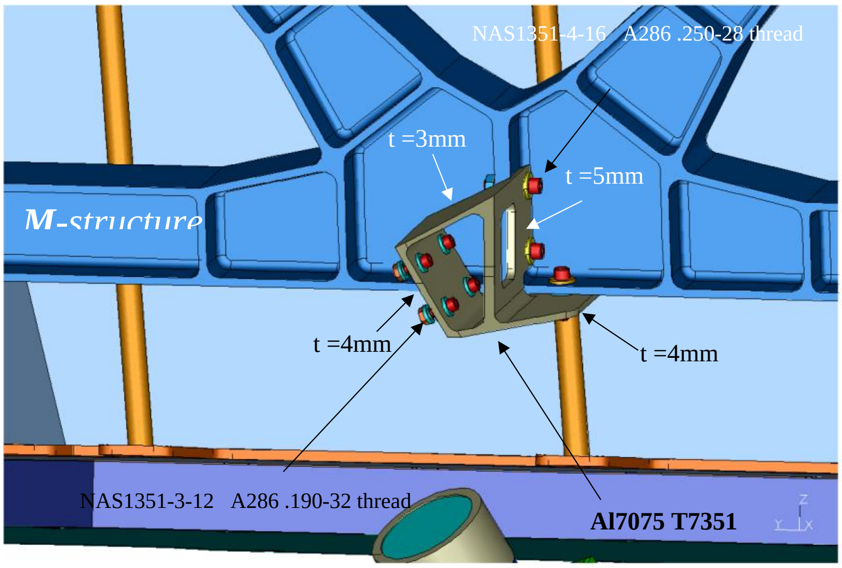
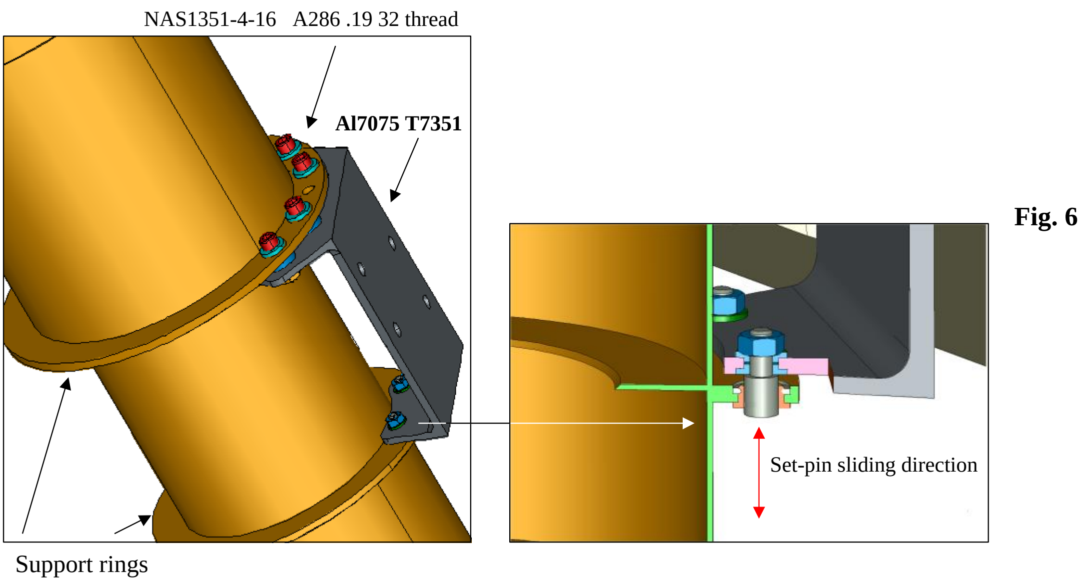


Fig. 5 Baffle Bracket M-structure side "BBM"

2.2.2 *BBB bracket*

Two rings machined at the baffle external side give the attachment points for the BBB bracket. Made of Al 7075 T7351 the bracket is rigidly connected to the baffle top ring by four 0.19-32 bolts. The lower connection consists in two set-pins fixed to the bracket and sliding into corresponding holes in the baffle external ring (fig.6).



Baffle Fig. 6 Baffle Bracket BBB-Baffle side "BBB"

Therefore the baffle, whose temperature strongly varies due to thermal environment, is free to deform along the baffle axis direction without introducing relevant stresses in the structure.

2.3 Bracket assembly

BBM bracket is pre-assembled to the M structure, while BBB bracket is pre-assembled to the baffle.
The baffle is positioned with reference to the lens in order to guarantee the nominal gap between baffle and lens (fig.7). This allows to by-pass the assembly tolerances between Tracker and TRD that will eventually result in a gap between the two brackets. The gap will be shimmed by devoted washers (fig.8).

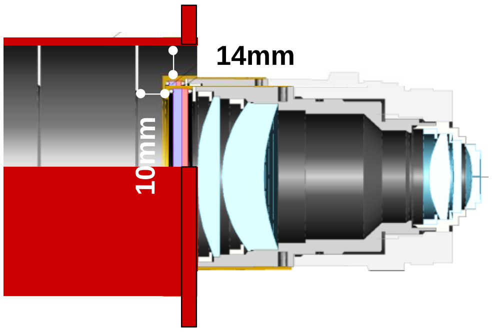


Fig. 7 Baffle /lens relative position

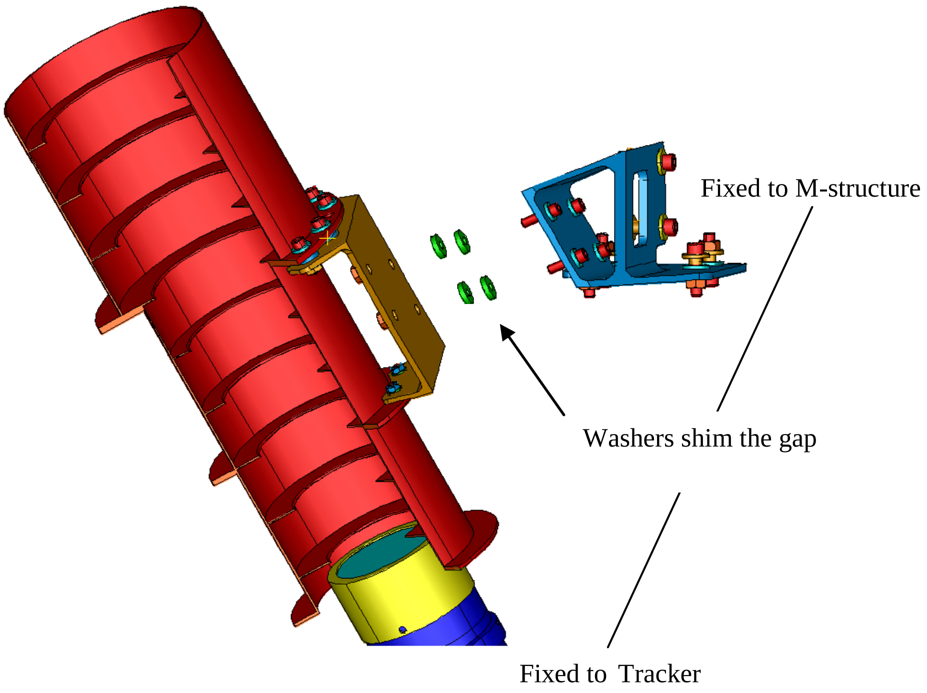


Fig. 8 Baffle Bracket assembly

2.4 Thermal decoupling

The star tracker thermal analysis shows that the baffle temperatures varies from +76°C for *B75-15-20-15* to –65°C for *B50-15-20-15* (see ASTS_Thermal_Report).
Baffle temperature gradient must have the minimum impact on the TRD M-structure.

To achieve these results Baffle has to be conductively and radiatively thermally decoupled from the TRD M-structure.

Conductance:
The bracket design foresees isolator washers at each bolted connection (fig.9).
A first assumption for the conductance between Baffle and M structure in a range 0.001÷0.01W/K produces, in the worst case (B_75-15-20-15, baffle temp=76°C) a local temperature increase on the M-structure at bracket location of ΔTmax=0.3÷3.9°C.

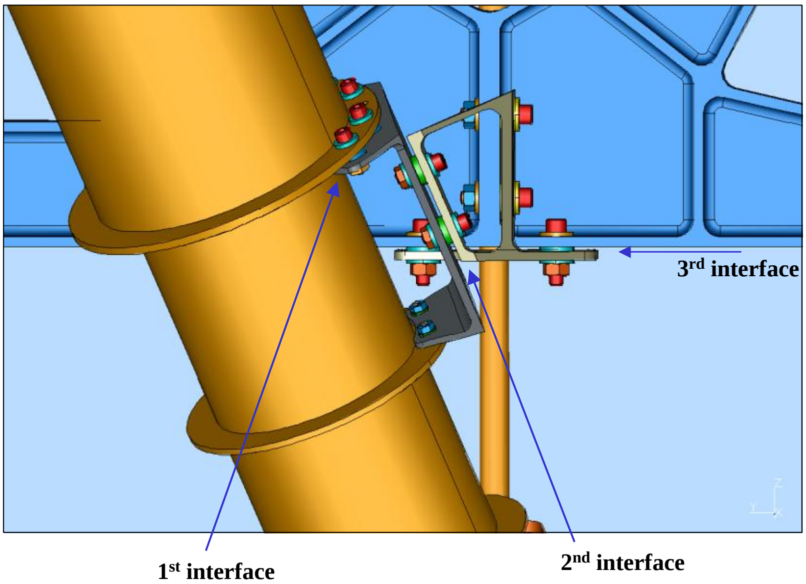


Fig. 9 Baffle Bracket isolated interfaces

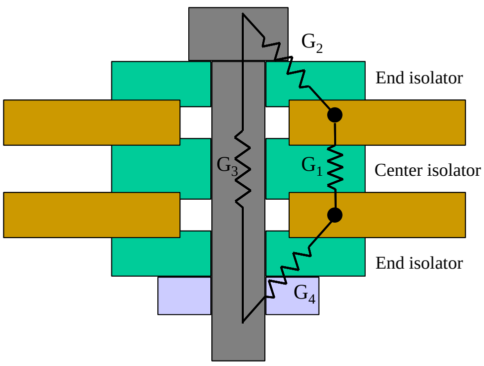


Fig. 10 Structure thermal isolation

In order to achieve a thermal conductance as close as possible to 0.01W/K thermal isolators are foreseen at each bolt.
Typical design, shown in fig.10, includes isolation both between the components being bolted together and under the bolt head and nut to avoid a thermal short though the bolt.In addition the isolator have a lip to prevent the bolt from shifting under launch vibration and contacting the isolated components (fig.11).

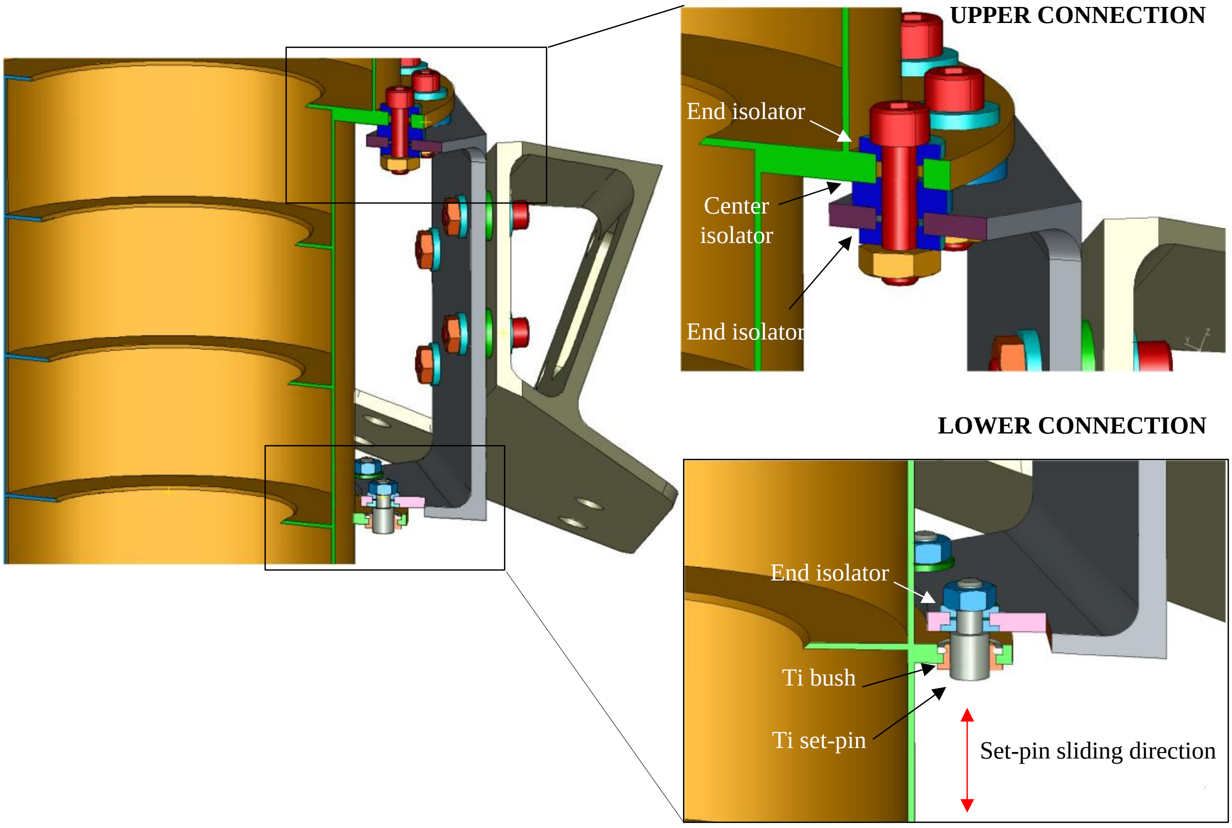


Fig. 11 Details of Bracket/Baffle thermal isolation

Radiation:
MLI sheets that protect the star tracker are MLI ID #1, MLI ID#7, MLI ID# 22S, MLI ID# 22P. Lens comes out from a cut out in MLI ID#1.
There is no conductive connection between baffle and lens. Minimum nominal gap between baffle and lens is 10mm
An MLI collar between baffle and star tracker support protects the lens periphery and avoids that light enters the lens (fig.12).

Baffle, internally black anodized and externally covered by silver tape, is not covered by MLI, but MLI is interposed between baffle and TRD.
A rectangular slot is cut in MLI ID 7, that cover the TRD, leaving one side of the rectangle uncut so to produce a tongue in the MLI ID 7
The MLI tongue is inserted between baffle and BBB bracket (gap about 25 mm).
The MLI vertical cuts are re-stitched together. The horizontal cuts are fixed to the baffle rings (fig.13).

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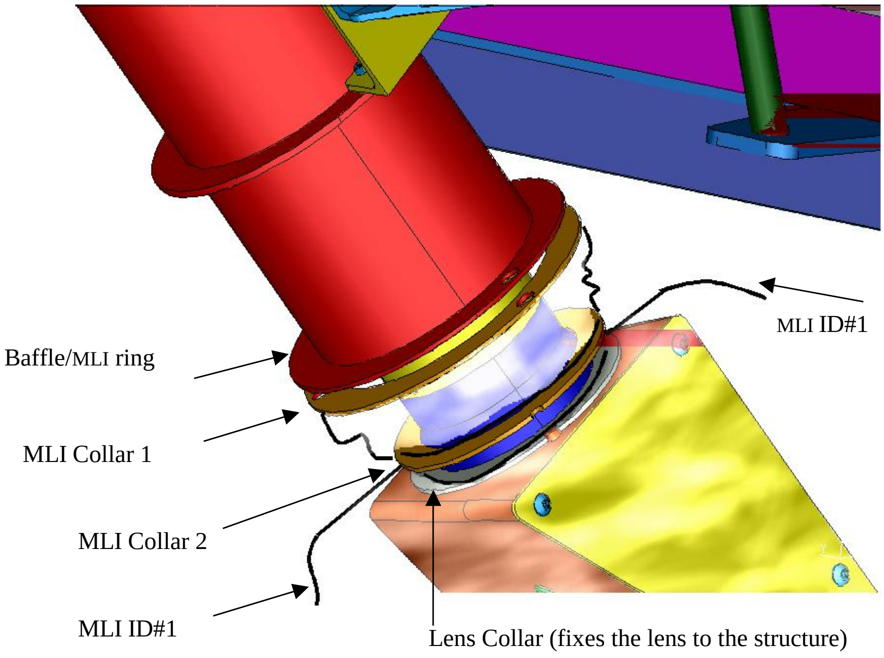

Fig. 12 Baffle-lens MLI collar

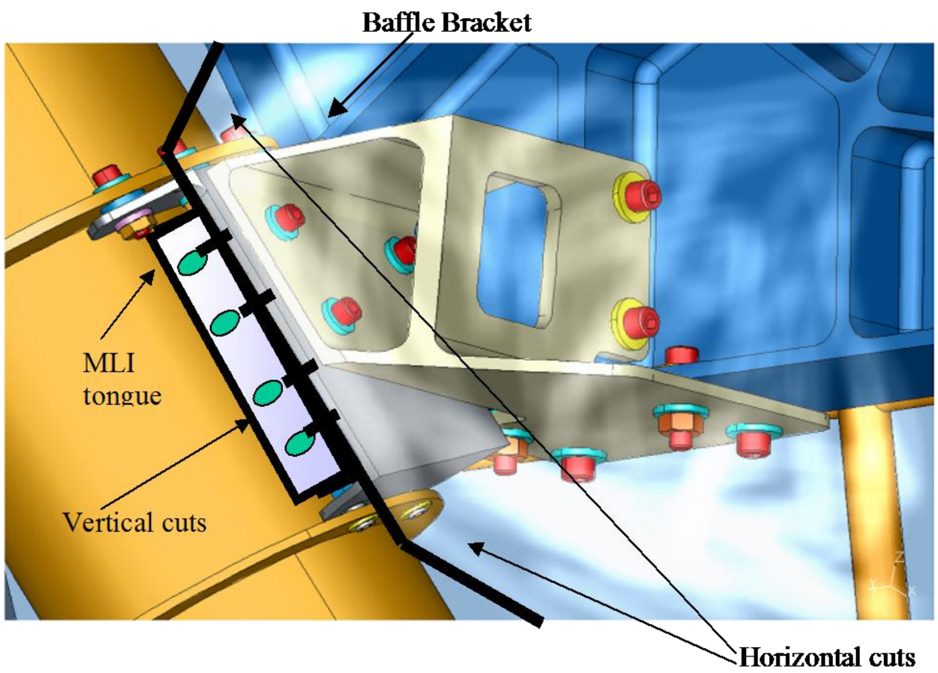

Fig. 13 Baffle Bracket MLI

2.5 Material

Material for the bracket is aluminum alloy Al7075 T7351.
Isolator washers are in G10 and Ti6Al4V
Baffle is Al6061 T6

3 Structural Analysis

3.1 Finite Element Model

A finite element analysis was performed to evaluate baffle static behavior in term of displacements, stresses and reactions at structures interfaces under critical load conditions that primarily occur during launch and landing.
A modal analysis was carried out to verify that the first significant structure natural frequency is above 50 Hertz.

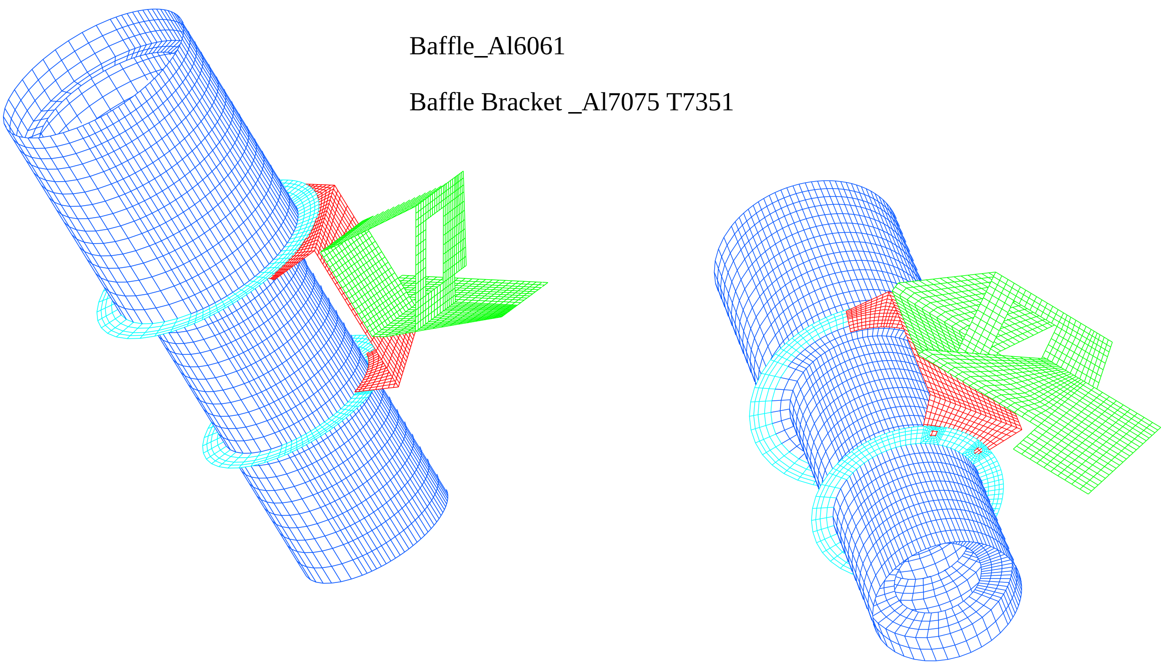

Fig. 14 BaffleFinite element mesh

Baffle and bracket are modeled with shell elements Mindlin theory based.
The bracket chamfers that increase structure stiffness are taken in to account by increasing corresponding elements thickness.

3.1.1 Type of element used

I-deas: element type 94_thin shell, 121_rigid bar, 23_rigid element, 136_translational spring.

3.1.2 Applied units

Length [mm], Mass [g], Force [N].

3.1.2 Type of material used

BAFFLE

Al Alloy 6061 T6

ρ=0.0027 g/mm^3 E = 73000 N/ mm^2 ν= 0.33

Fty=240 N/mm^2, Ftu= 290 N/mm^2, Su= 186 N/mm^2

BAFFLE BRACKET

Al Alloy 7050 T7351

ρ=0.0028 g/mm^3 E = 71016 N/ mm^2 ν= 0.33

Fty= 324.06 N/mm^2, Ftu=406.79 N/mm^2, Su= 262 N/mm^2

3.2 Constraints and Loads

Constraints:

Bolts connecting the Bracket to the M-structure are modeled constraining translations and rotations at corresponding nodes.

Bolts connecting the BBB bracket to the BBM bracket and the BBB bracket to the Baffle are modeled by coupling all the nodes Degrees Of Freedom (DOF) of the two parts at bolts location. Set-pins at BBB bracket and Baffle are modeled by coupling only translations in the plane normal to baffle axis laving free the translational DOF along baffle axis.

Loads:

The load cases considered are the Star Tracker mass subjected to an acceleration vector

Acceleration vector imposed:

±40g in one direction with ±10g simultaneously applied in the other two directions according to Document JSC-28792; different load cases were considered by sweeping the direction of the acceleration vector.

3.3 Static analysis: stresses and displacements

Baffle and bracket predicted static behavior satisfies the safety requirements.

The calculated stress levels and displacement under different load cases are summarized in tab.1 for each structural component. Yeld and Ultimate Margins of Safety (MoS) are listed in the same table.

$$MS_{yeld} = \frac{Yeld\ \ Stress}{FS_y \times Limit\ \ Stress\,(Von\ Mises)} - 1$$

$$MS_{ult} = \frac{Ultimate\ \ Stress}{FS_{ult} \times Limit\ \ Stress\,(Max\,\mathrm{Pr}\,incipal)} - 1$$

with $FS = Factor\ \ of\ \ Safety$

$$FS_y = 1.25 \qquad FS_{ult} = 2$$

Maximum stress and corresponding minimum positive Margin of Safety occurs at bracket BBM in correspondence of one of the bolt that connects the Bracket to the M-structure(fig.15): Von Mises Stress=182Mpa for load case (10,10,40)g resulting in a Yeld MoS=0.42 and Ultimate MoS=0.01.

LOADS:			baffle bracket				
Acceleration *(g)*			Limit Stress *[N/mm2]*		Max Displacement	Margin of Safety	
x	y	z	*Von Mises*	*Max Principal*	*[mm]*	*Yeld*	*Ultimate*
40	10	10	98.7	109.0	1.51	1.63	0.87
10	**40**	10	90.7	101.0	0.84	1.86	1.01
10	10	**40**	182.0	202.0	2.56	0.42	0.01
-40	-10	-10	98.7	112.0	1.51	1.63	0.82
-10	**-40**	-10	90.7	96.0	0.84	1.86	1.12
-10	-10	**-40**	182.0	171.0	2.56	0.42	0.19

Tab.1 Stress, Displacement and MoS

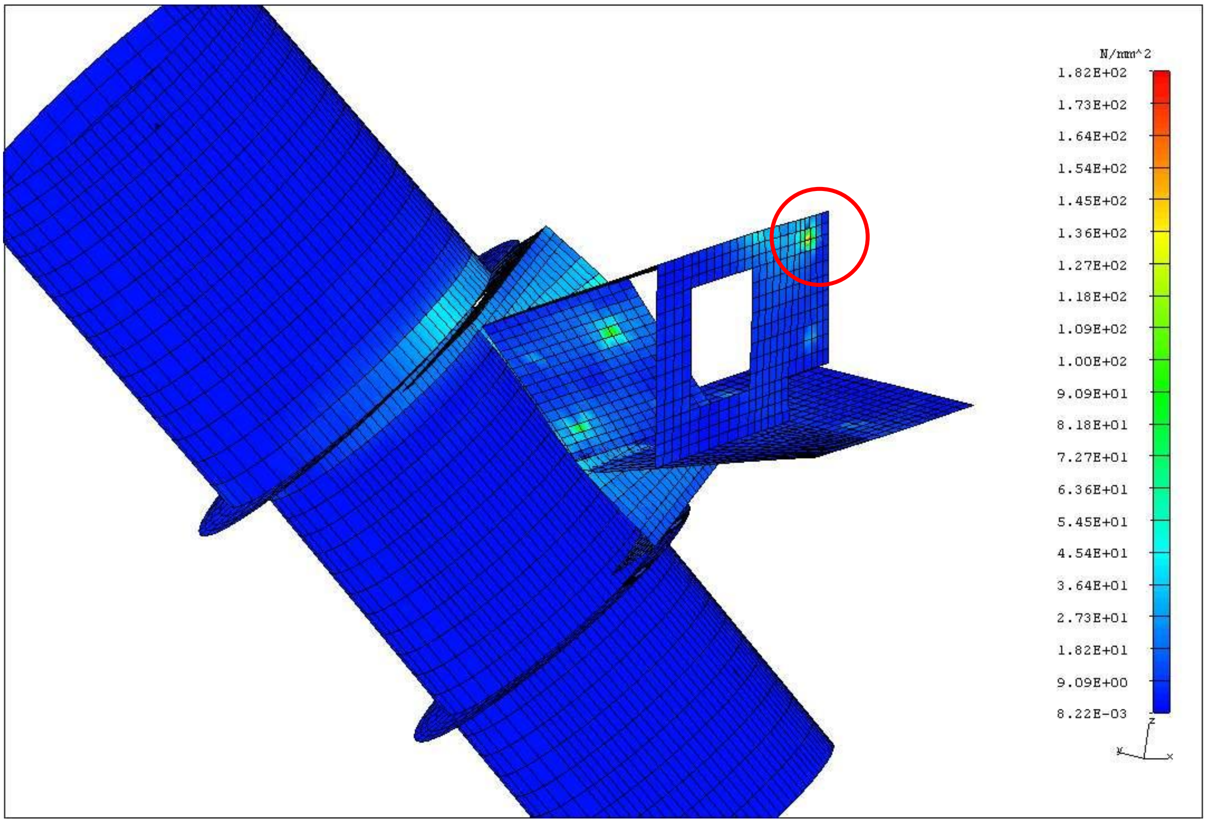

Fig. 15 Von MisesStress; Load case (10,10,40)g

3.4 Bolts analysis

The maximun reaction forces at the bolt locations are given in tab.2.
Reported are Forces [N] per node where each screw is modeled by one node.
Bolts numbering is shown in fig.16
The reaction distribution in the brackets, for the worst case (MoS= 0.05), occurring at one of the bolts at interface between BBB bracket and BBM bracket, is shown in fig.17

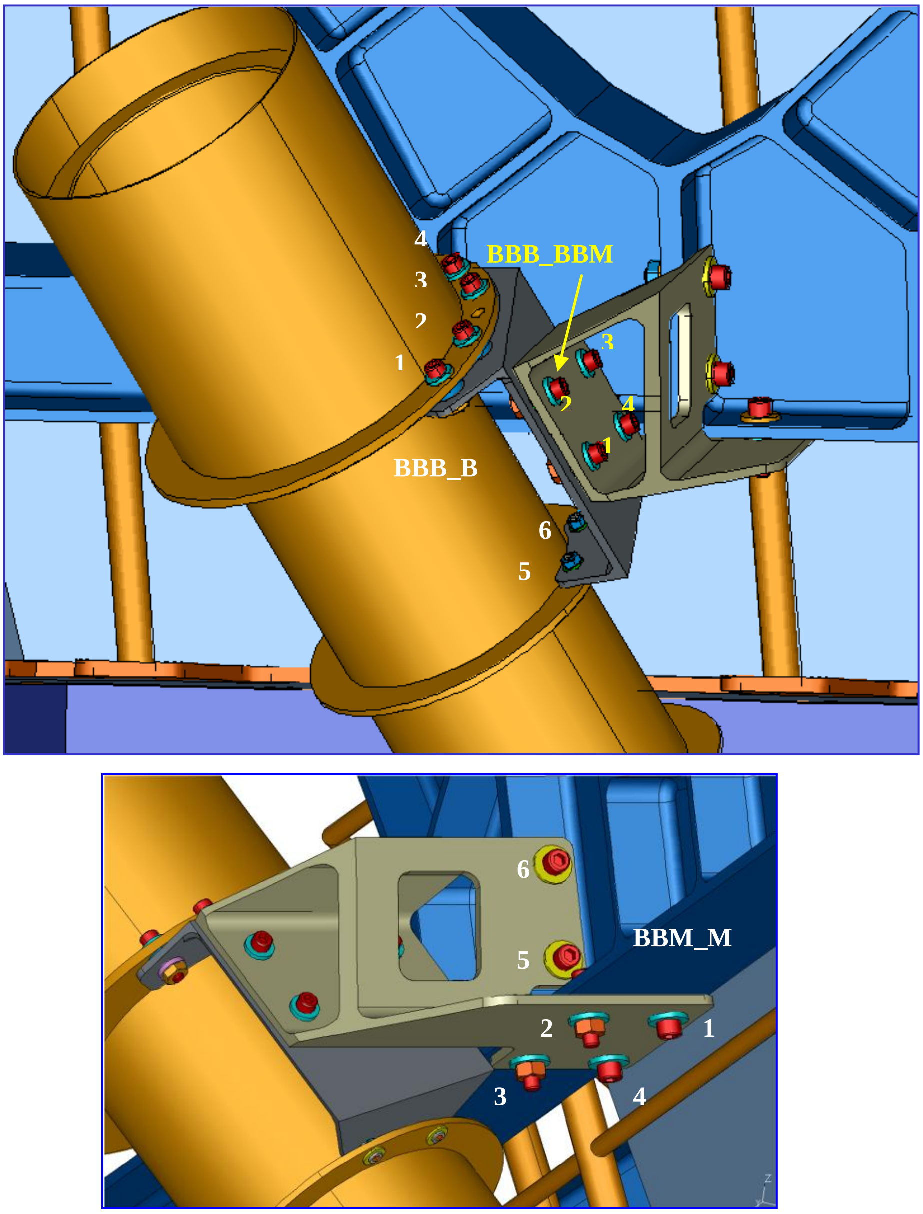

Fig. 16 Bolts numbering

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LOAD CASE	BOLT no (*)		TENSION [N]	SHEAR [N]	BOLT std	MARGIN OF SAFETY	TYPE
(-10,-10, -40)g	BBM / M	6	379	555.90	NAS1351N4-16	0.10	tension yeld
(10,10, 40)g	BBM /BBB	3	545.00	57.80	NAS1351N3-12	0.05	combined ultimate
(-10,-10, -40)g	BBB / B	4	168	63.3	NAS1351N3-12	0.09	combined ultimate

Tab.2 Bolt loads and MoS

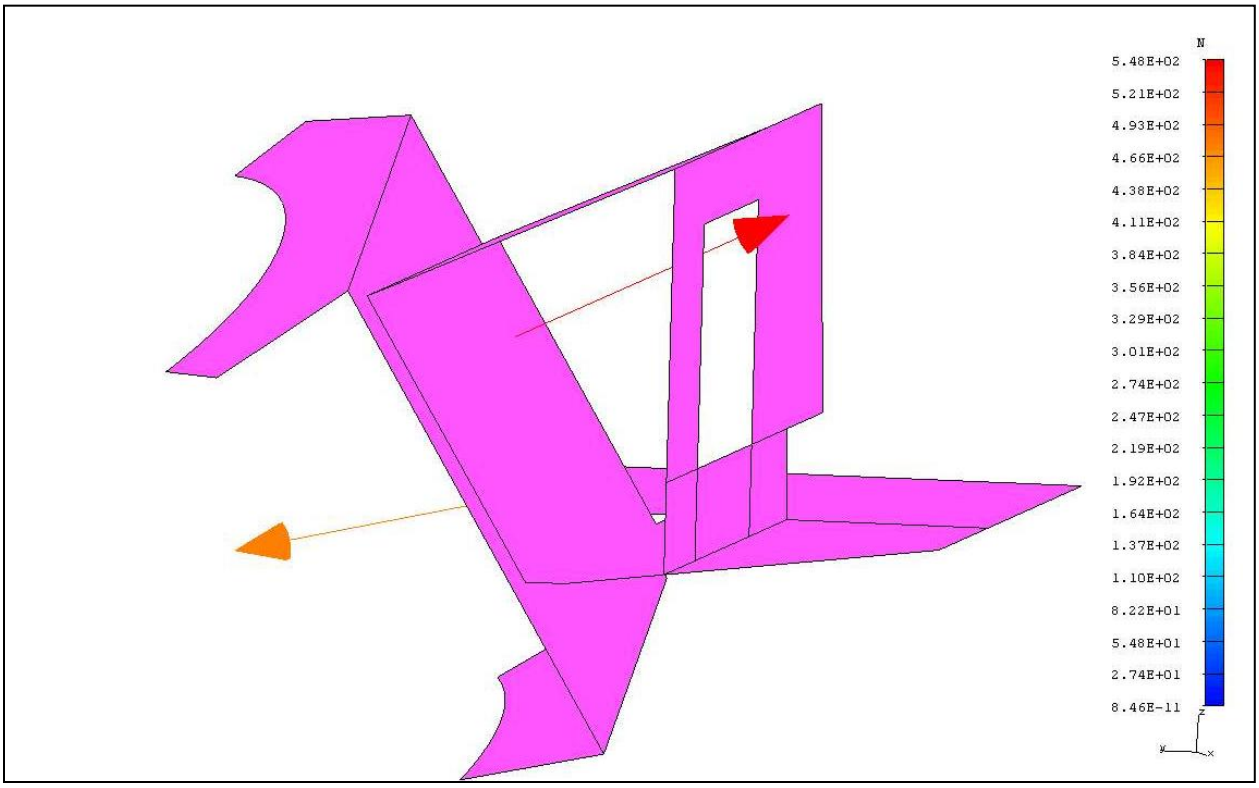

Fig. 17 Minimum Bolt MoS= 0.05 at BBM/BBB _3 for load case (10,10,40)g

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3.5 Fail Safe Analysis

A fail-safe analysis, with the highest loaded fastener removed, was performed at all bolted interfaces and Margins of Safety were recalculated. The Factor of Safety used for fail-safe analysis is 1.0 for both yield and ultimate.
Resulting bolts new MoS are all positive and are listed in tab4.
Fig.18-19 show bolts load and stress in the bracket assuming the failure of the Bolt BBM-M-6 at the interface with the M-structure. The corresponding MoS for the stress in the bracket are listed in tab.5.

LOAD CASE	FAILED BOLT no (*)		MAX LOADED BOLT no (*)		TENSION [N]	SHEAR [N]	BOLT std	MARGIN OF SAFETY	TYPE
(-10,-10, -40)g	BBM / M	6	BBM / M	5	530.0	1262.70	NAS1351N4-16	0.42	combined ultimate
(10,10, 40)g	BBM /BBB	3	BBM /BBB	2	492.00	183.40	NAS1351N3-12	0.26	combined ultimate
(-10,-10, -40)g	BBB / B	4	BBB / B	3	143.00	56.3	NAS1351N3-12	0.23	combined ultimate

Tab.4 Fail safe Bolt loads and MoS

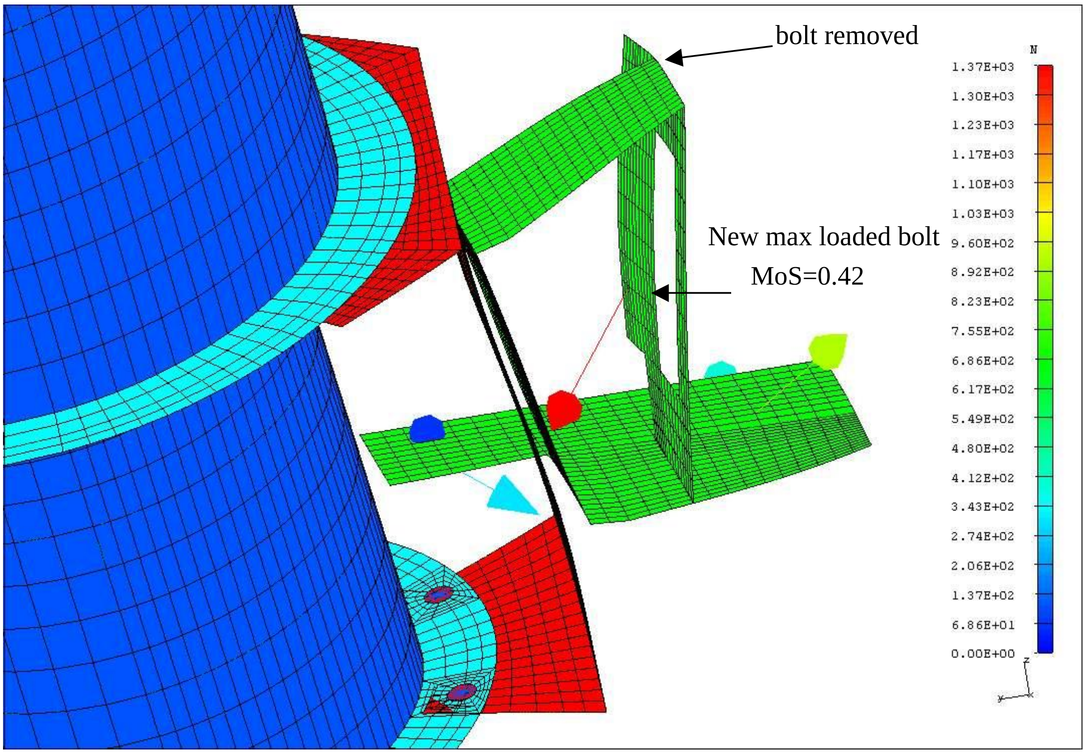

Fig.18 Fail safe Bolt loads and MoS at the bolted interface between BBM bracket and M-structure

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fail safe			baffle bracket			
Acceleration *(g)*			Limit Stress *[N/mm2]*		Margin of Safety	
x	y	z	*Von Mises*	*Max Principal*	*Yeld*	*Ultimate*
-10	-10	-40	307	326	0.06	0.25

Tab.5 Fail safe analysis: MoS stress in the structure assuming failure of one bolt

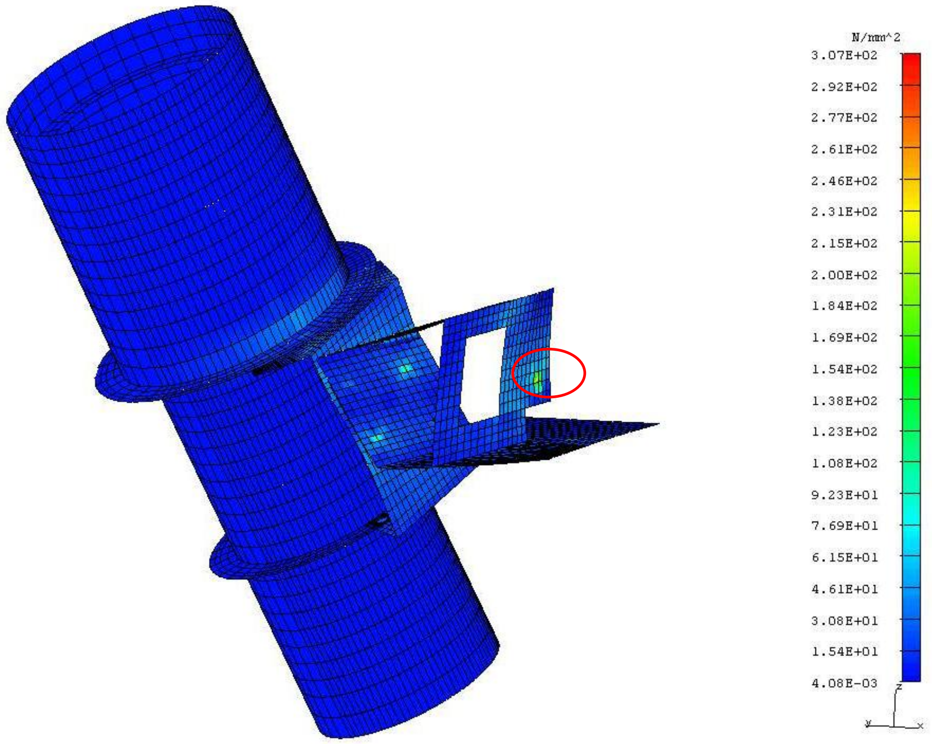

Fig.19 Fail safe analysis: stress in the bracket under the new max loaded bolt

4 Thermo-elastic Analysis

A thermo elastic analysis was performed to evaluate the thermal deformation, due to the temperature reached by the different components, and the consequent thermal stress occurring where these deformation are constrained.
According to the thermal analysis (see ASTS_thermal analysis) the max predicted temperature for the baffle is 76°C (for *B75-15-20-15).*
Based on this result for the thermo-elastic analysis the following conservative assumption have been made:

Baffle temperature: 80°C
Bracket temperature: 22°C

The second assumption is based on the conservative hypothesis that the baffle is completely thermally decoupled from the bracket and the M-structure that are assumed to stay at 22°C. Based on these boundary condition the analysis predicts a thermal deformation shown in fig.20, that gives the evidence of the set-pins sliding action, at the lower connection, between bracket and baffle. This action leaves the baffle the freedom to deform in the axial direction reducing the stress level (fig.21). Max_stress at bracket and MoS are listed in tab 6.

LOADS:	
temperature	
baffle	80
bracket	22

baffle bracket				
Limit Stress *[N/mm2]*		Max Displacement *[mm]*	Margin of Safety	
Von Mises	*Max Principal*		*Yeld*	*Ultimate*
105	116	0.329	1.47	0.75

Tab.6 Bracket Stress and MoS under temperature load

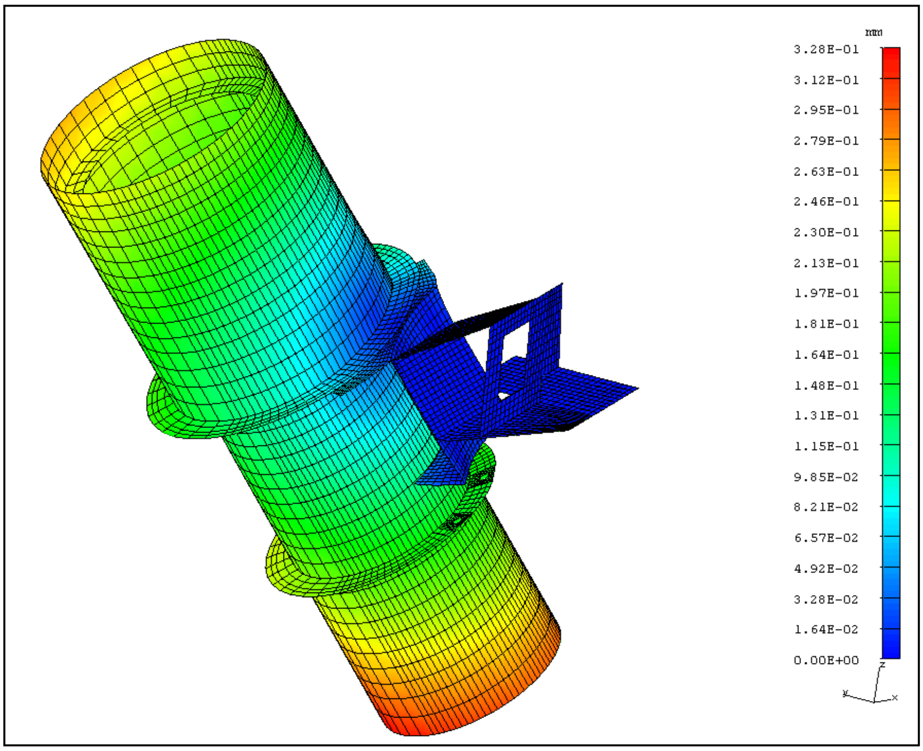

Fig.20 Thermo-elastic analysis: Displacement

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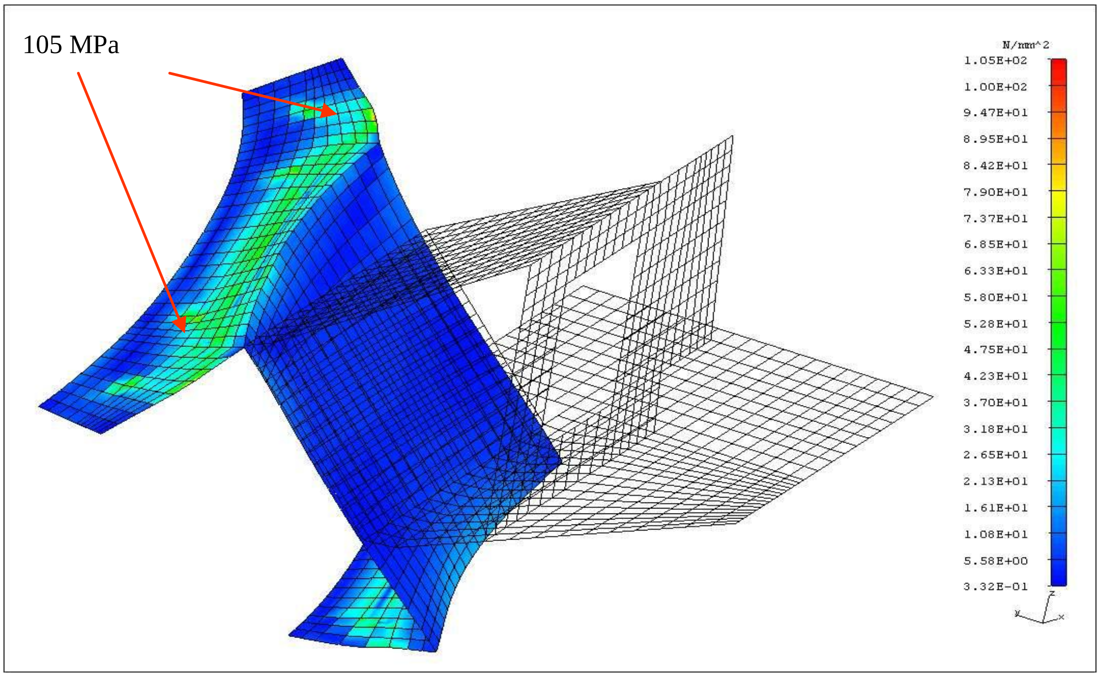

Fig.21 Thermo-elastic analysis: **Stress**

Predicted bolts load and positive MoS are listed in tab.7 and shown in fig.22.
A fail safe analysis was performed removing the bolt BBB_B_2 and verifying that the new load distribution on the other bolts doesn't cause failure (tab.8, fig.23).

LOAD CASE	BOLT no (*)		TENSION [N]	SHEAR [N]	BOLT std	MARGIN OF SAFETY	TYPE
THERMAL	BBB / B	2	0.0	808.80	NAS1351N3-12	0.09	COMBINED ULTIMATE

Tab.7 Bolt load and MoS

LOAD CASE	FAILED BOLT no (*)		MAX LOADED BOLT no (*)		TENSION [N]	SHEAR [N]	BOLT std	MARGIN OF SAFETY	TYPE
THERMAL	BBB / B	2	BBB / B	3	8.1	915.10	NAS1351N3-12	0.42	COMBINED ULTIMATE

Tab.8 Bolt Fail Safe Analysis: load and MoS

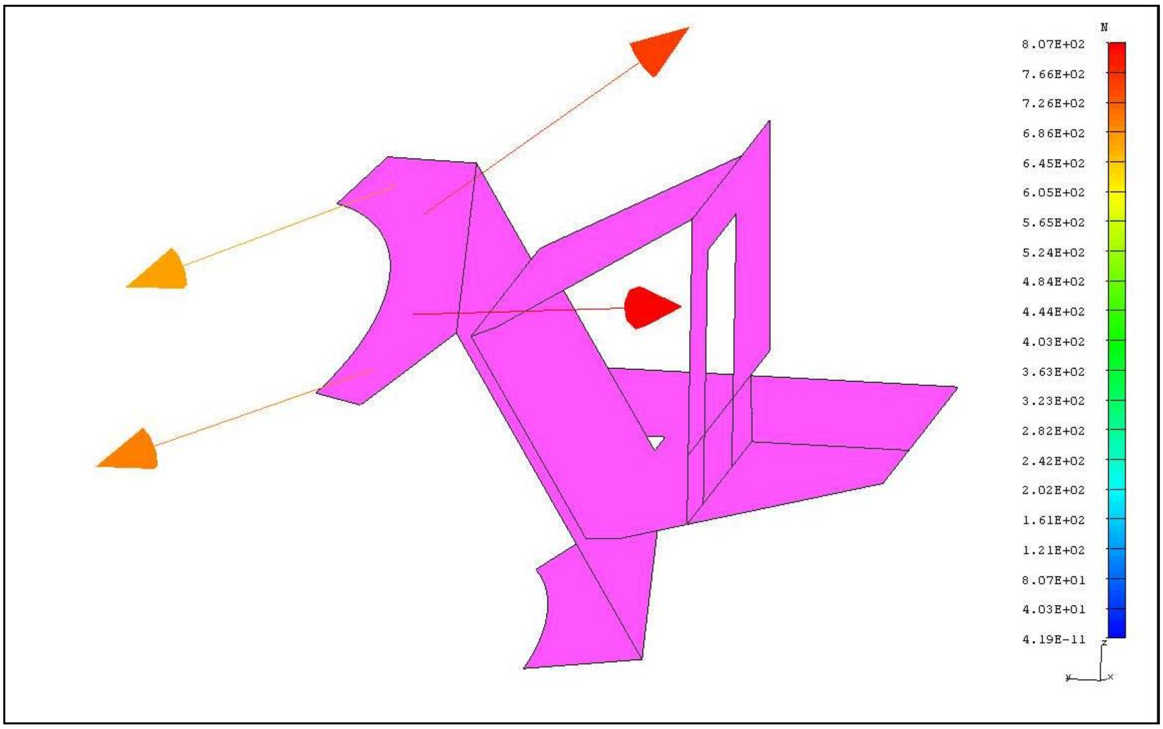

Fig.22 Thermo-elastic analysis: Bolt loads

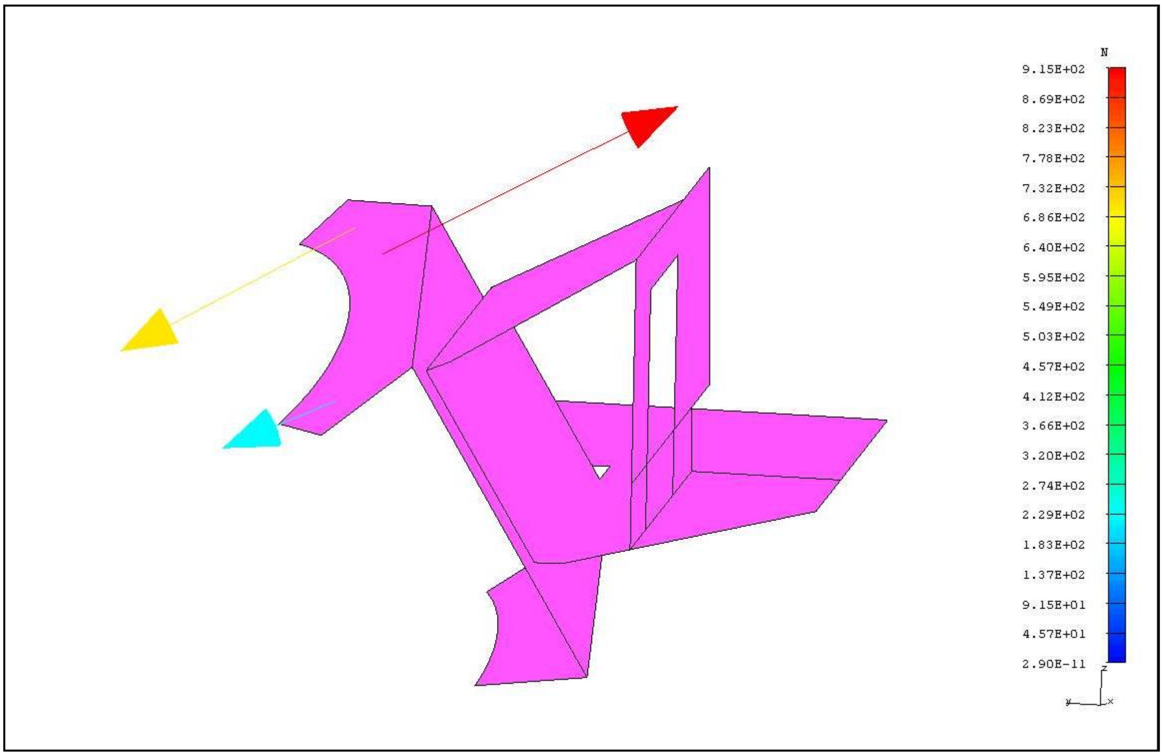

Fig.23 Thermo-elastic analysis: Fail safe Bolt loads

5 Modal Analysis

The modal analysis predicts a first frequency at 68.6 Hz well above the limit of 50 Hz.
The modal shapes of the first two normal modes are shown in fig 24 and 25.
In Tab.9 the first ten frequencies with the normalized effective mass, showing the fraction of mass that participates to the mode, are listed.
The analysis was performed clamping the node corresponding to the bolts at interface with the M-structure.
In order to evaluate any compliance coming from this interface the clamped connection was substituted by a tridirectional translational spring.
An indicative value was found for the K of the spring by tuning this value till the first frequency reach the limit of 50Hz (K=1200N/mm) .

NORMALIZED EFFECTIVE MASSES				
	MODE	X	Y	Z
1	**68.6**	0.24	0.01	0.06
2	103.3	0.01	0.24	0.20
3	223.1	0.00	0.32	0.19
4	237.8	0.12	0.00	0.02
5	368.9	0.25	0.12	0.06
6	736.6	0.06	0.00	0.02
7	792.5	0.00	0.01	0.00
8	907.2	0.04	0.00	0.10
9	1084.7	0.00	0.12	0.03
10	1302.4	0.02	0.01	0.05

Tab.9 Normal modes and effective masses

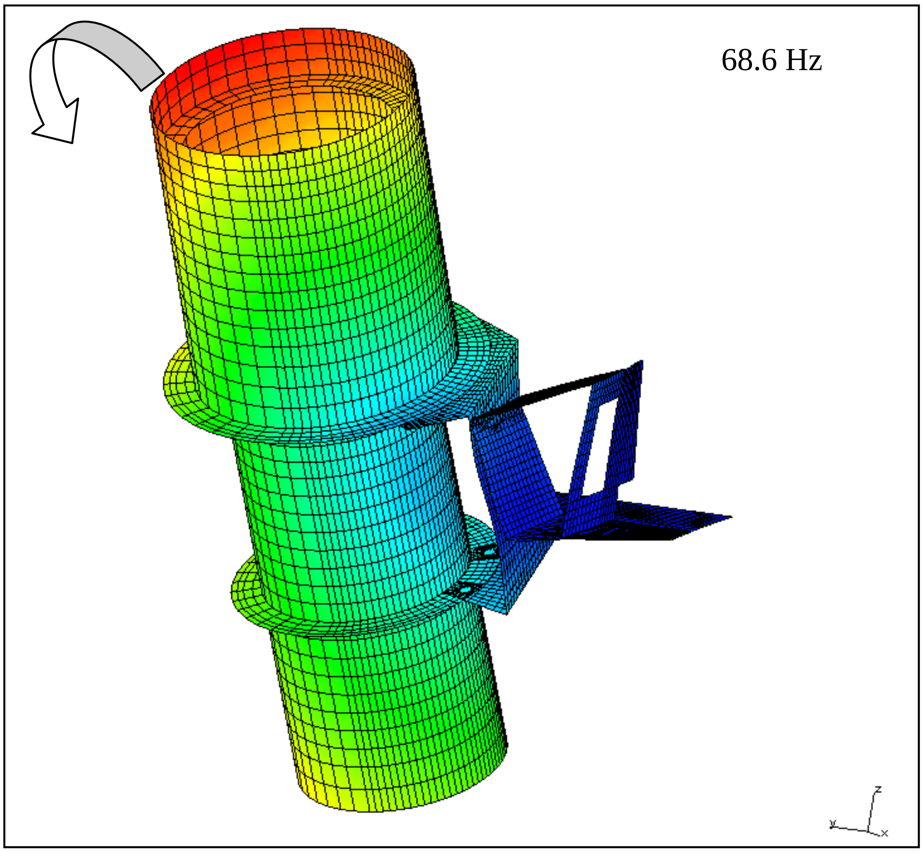

Fig.24 First mode

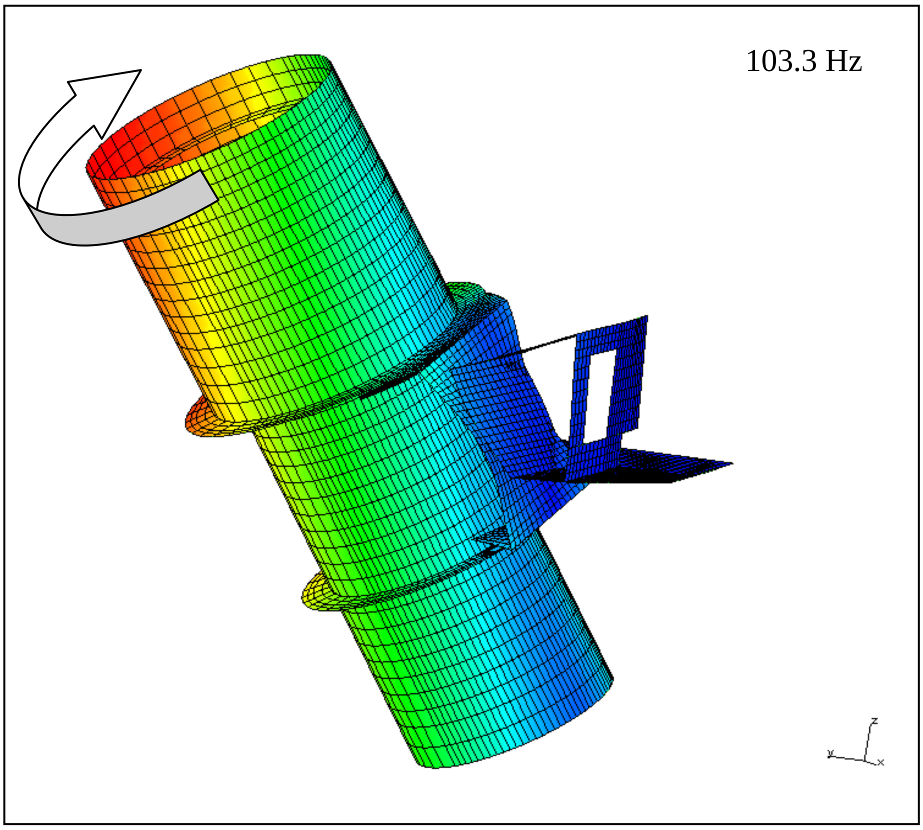

Fig.25 Second mode

INDEX